

"Express Mail" Mailing Label Number EL852684903US  
 Date of Deposit: OCTOBER 9, 2001  
 I hereby certify that this paper or fee is being deposited  
 with the United States Postal Service "Express Mail"  
 Post Office to Addressee" service under 37 C.F.R. 1.10 on the  
 date indicated above and is addressed to:  
 Assistant Commissioner for Patents Washington, D.C. 20231.

*Hilary M. McNulty*  
 By: Hilary M. McNULTY

# WIRELESS CONTROLLER AND APPLICATION INTERFACE FOR AN MRI SYSTEM

## Background of the Invention

5 The present invention relates to the diagnostic  
 imaging arts. It has particular application in  
 conjunction with wireless communication in a magnetic  
 resonance setting and will be described with particular  
 reference thereto. It will be appreciated, however, that  
 the invention is also applicable to other modalities  
 including, but not limited to, CT, SPECT, and PET.

10 Magnetic resonance (MR) imagers generate high  
 magnetic fields through an imaging region. A typical by-  
 product of the production of this field is a magnetic  
 fringe field that can extend several meters beyond the  
 physical apparatus. Although the excitation fields are  
 high, the induced resonance signals are weak comparable  
 15 with ambient television and radio signals. In order to  
 minimize disruption to and interference from the  
 surroundings in an environment such as a hospital or  
 clinic, the magnets are often built within specially  
 shielded suites to prevent the fringe field from affecting  
 20 surrounding objects or people.

As a result, control hardware components for an  
 MR apparatus are placed outside the shielded room. When  
 controlling the apparatus and recalling images, the  
 operator is outside the suite at the control station.  
 25 This typically leaves the patient unattended during the  
 scan. In many patients, being alone and in such a  
 constricted area such as the bore of an MR device can

cause increased anxiety and restlessness, ultimately degrading image quality.

Typically, power and control cables are fed into the MR imaging suite. Cables typically present a problem in that they can introduce radio frequency (RF) disturbances into the imaging volume and receive ambient RF signals. Ultimately, these RF disturbances manifest as imaging artifacts in final images. Typically, these cables are heavily shielded to prevent interference with radio frequency fields produced by the MR device, and vice versa, to prevent the RF fields from corrupting information fed through the cables. As a result of shielding, these cables become quite bulky, and present obstacles within the MR suite. This can restrict access to the MR device from wheelchairs, gurneys, walkers, or other mobility limited patients, as well as lessen mobility of the operator, or other support staff about the device.

A further disadvantage of cables in the MR suite is that detuning of the coils is possible. RF receive coils become less sensitive to the resonance frequency, thereby decreasing the signal to noise ratio. In addition, cables can focus RF power onto small portions of the patient, posing potential health hazards.

The present invention provides a new and improved method and apparatus which overcomes the above-referenced problems and others.

#### Summary of the Invention

In accordance with one aspect of the present invention, a magnetic resonance apparatus is provided. A magnet assembly generates a main magnetic field through a subject in an imaging region. A sequence control system generates magnetic resonance sequences. An RF coil receives resonance signals from the imaging region. An image processing system processes the resonance signals into images. A wireless interface provides wireless

communication between systems of the magnetic resonance apparatus.

5 In accordance with another aspect of the present invention, a method of magnetic resonance is provided. A main magnetic field is induced through a subject in an imaging region. Magnetic resonance is excited and manipulated. Requests to a control console are made with radio frequency signals. Resonance signals are received, demodulated, and reconstructed into an image representation of the subject in the imaging region.

10 In accordance with another aspect of the present invention, an improvement to a magnetic resonance imaging system includes communicating within a magnetic resonance suite with radio frequency communications signals.

15 One advantage of the present invention resides in improved mobility for patients and operators around an MR device.

Another advantage resides in the ability of the operator to remain close to the patient during the scan.

20 Another advantage resides in the reduction of cumbersome material within the medical imaging suite.

Another advantage resides in the ability of the operator to control the MR device from locations other than the control console.

25 Still further benefits and advantages of the present invention will become apparent to those skilled in the art upon a reading and understanding of the preferred embodiments.

#### Brief Description of the Drawings

30 The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 is a diagrammatic illustration of wireless communication in an MR environment, in accordance with the present invention;

FIGURE 2 is a diagrammatic illustration of a hand held remote interface unit, in accordance with the present invention.

#### Detailed Description of the Preferred Embodiment

With reference to FIGURE 1, an open main magnet assembly 10 which generates a temporally constant main magnetic field, typically denoted  $B_0$ , vertically through an imaging region 16 is disposed in a magnetic resonance suite A. It should be noted that although depicted in conjunction with an open magnet system, the preferred embodiment of the present invention is equally applicable to bore type systems. A subject 12 is disposed on a patient support located in the imaging region 16 of the magnet assembly 10. The main magnet assembly, 10 is located within a magnetic resonance suite, which is preferably shielded to be impervious to electromagnetic radiation, particularly in the radio frequency band.

A sequence control system B generates magnetic resonance imaging sequences. A keyboard 18 or touch screen 19 receives operator control commands. A sequence control processor 20 withdraws a selected magnetic resonance sequence from a sequence memory 22. A gradient field controller 24 produces gradient waveforms in accordance with the selected sequence. Concurrently, an RF pulse controller 26 generates RF pulse patterns in accordance with the selected sequence.

At least an antennae 28 of a first wireless interface, such as a transceiver 30, is located within the imaging suite A. The wireless interface 30 encodes (preferably digitally) and transmits the gradient waveforms and the RF pulse patterns on a high frequency carrier wave to a second transceiver 32. The second transceiver decodes the gradient pulse waveforms and communicates them

to RF shielded gradient amplifiers 34 which are connected with gradient coils 36. The gradient coils 36 impose gradient fields along the main magnetic field  $B_0$  thereby spatially encoding the main magnetic field. The second transceiver also decodes the RF pulse pattern information and supplies RF pulse information to an RF shielded transmitter 40. In one embodiment, the transmitter is connected directly with the RF coil. In the illustrated embodiment, the transmitter is connected to a third transceiver 42 which is in radio communication with a fourth transceiver 44 on an RF coil 46. The RF coil 46 includes a coil identification. A handshaking protocol between transceivers 42 and 44 identifies the coil to the rest of the system. In a system with multiple local or other receive coils, each receive coil has an identification so the system can identify each coil with a handshaking protocol. The third and fourth RF transceivers 42, 44 share a similar relationship to the first and second RF transceivers 30, 32 as discussed previously. The RF coil 46 transmits the RF pulses into the imaging region 16, exciting and manipulating magnetic resonance in accordance with the selected sequence. The RF receive coil receives the resultant resonance signals which are transmitted to the wireless interface 30 directly or via the second and third transceivers 32, 42.

Preferably, the scanner includes the whole body RF coil 46 and a plurality of localized coils, such as head coil 48. The RF coils each include a unique identifier and a transceiver 44'. The transceivers 42 and 44, 44' are preprogrammed with a handshake protocol by which the transceiver 42 interrogates the transceiver 44, 44' to and receives an identification of the coil. The coil information is communicated to the sequence control system to verify that the correct coil is installed and to make any sequence adjustments to customize the sequence to the specific RF coil.

In the preferred embodiment, the antenna 28 of first transceiver 30 is mounted to an inside wall of the magnetic resonance suite A. Cables connecting the first transceiver 30 to the antenna 28 are fed through the wall.

5 The second transceiver 32 is preferably mounted adjacent the magnet assembly, with as little cable as possible connecting it to the gradient amplifier 34, the transmitter 42 (in the direct wire embodiment), and other systems of the MR apparatus. Preferably, the first and  
10 second transceivers 30, 32 have a line of sight with each other free from any radio-opaque materials in the magnetic resonance suite.

In the preferred embodiment, the first and second transceivers 30, 32 transmit in a higher frequency  
15 band than the RF coil 44. In a 1.5 T magnet, hydrogen dipoles (most commonly used for imaging) precess at approximately 64 MHz; in a 0.75 T magnet, the resonance frequency is approximately 32 MHz. In order to tip these dipoles into the transverse plane, as is common practice,  
20 RF pulses containing frequency components close to this precession frequency are synthesized by the RF pulse controller 26. In the preferred embodiment, the transceivers 30, 32, 42, 44 transmit carrier waves of approximately 2.4 GHz. This ensures that RF signals from  
25 the transceivers do not interfere with RF signals used for imaging. Although about 2.4 GHz is the preferred frequency range, any frequency above about 500 MHz is acceptable. Frequencies below 500 MHz can begin to interfere with the RF signals used for excitation and  
30 manipulation, especially in higher field systems where the dipoles precess with higher frequencies.

Signals from resonating dipoles are detected by the RF coil 46 or dedicated receive coils 48 and preamplified. The detected resonance signals are encoded  
35 and transmitted by the patient side transceiver 44 either to the transceiver 42 or directly to the transceiver 30. The first transceiver 30 receives and decodes the

40500T 00000000

resonance signals and sends the resonance signals to an image processing system C. A receiver 50 preferably digital, demodulates the resonance signals. The demodulated resonance signals are reconstructed into an  
5 image representation of the subject 12 in the imaging region 16 by a reconstruction processor 52. The images are stored in a volumetric image memory 54, where they remain until needed. A video processor 56 extracts portions needed for viewing, which portions are displayed  
10 on a human readable display 58 such as a video monitor, LCD display, active matrix monitor, or the like.

With reference to FIGURE 2 and continuing reference to FIGURE 1, the preferred embodiment of the invention includes a hand-held remote control interface  
15 unit 60. The remote control unit 60 allows the operator to communicate with the sequence control system and the image processor system of the MR apparatus. In the preferred embodiment, the remote unit 60 includes a display 62. From the display 62, the operator is able to  
20 observe information regarding the current scan. Such information includes, but is not limited to, elapsed scan time, estimated remaining scan time, selected portions of reconstructed images, available options, etc. Such devices as palm pilots, laptop computers, and the like are  
25 contemplated as available embodiments. Cellular phone units are also contemplated.

The remote unit also includes a user input portion 64. This portion allows the operator to relay instructions to the sequence control and image processing  
30 systems. Instructions contemplated can be as simple as ordering the commencement or abortion of an imaging sequence, and more complex, such as selecting sequences, adjusting RF pulse bandwidth, or changing the size of the k-space data matrix. Instructions can also be sent to the  
35 scanner to start or stop a sequence, adjust patient position, select among receive or transmit coils, establish voice communication with the patient, and the

like. The input portion 64 may include a touch screen, keyboard, voice recognition, mouse, or any combination thereof. The input portion 64, of course, is not limited to these devices.

5           The remote unit 60 includes a transmitter 66 and a receiver 68 that facilitate communication. These two portions are connected to an antenna similar to those found in cellular phones. The 2.4 GHz frequency band does not interfere with the RF pulses which excite and  
10       manipulate magnetic resonance or the resultant resonance signals. Moreover, when the device is operated within the shielded suite, it does not interfere with cellular communications in the area. An exemplary realization of such a transceiver is embodied in the Bluetooth™  
15       technology by Ericsson mobile phones.

          Also included in the remote unit 60 is a microprocessor 70. The microprocessor 70 processes input from the operator and information transmitted by the first transceiver 30 for display on the remote unit 60.  
20       Optionally, the microprocessor 70 is included elsewhere, remote from the hand-held unit 60.

          The remote unit 60 includes a power source. The power source is selected according to the power consumption needs of the remote unit 60. Typical power  
25       sources include batteries (disposable or rechargeable), storage capacitors which are charged by AC power or power from RF pulses, and solar cells.

          In another application of the preferred embodiment, the remote unit 60 is also used in conjunction  
30       with peripherals not immediately associated with the MR apparatus. Such devices include ECG machines, respirators, and the like. Communication between the remote unit and the peripheral devices allow the operator to see patient blood pressure, heart rate, and other  
35       variables on the remote unit 60. Preferably, each peripheral device has at least a transmitter that transmits directly to the remote unit 60. Optionally, if



5           In an alternate embodiment, the remote unit is used outside of the imaging suite. In this embodiment, The suite would not be shielded against high frequency RF signals in order to let information to pass into the room.

In another alternate embodiment, the remote unit 60 is used in conjunction with a CT or nuclear imaging scanner. In this embodiment, a greater range of radio frequencies are available, as there are no RF imaging pulses with which to interfere.

The invention has been described with reference to the preferred embodiment. Modifications and alterations will occur to others upon a reading and understanding of the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.